may possibly be sanidine. It is often rounded or broken in outline, is always greatly cracked, and contains many inclusions of a pale brown glass. One grain, indeed, consists very largely of glass, in which the crystalline parts are, so to say, embedded. This suggests that the mineral has been melted down *in situ* along the lines of natural fracture, rather than that it has incorporated the glass in crystallising. There are occasional cavities in the felspar, with bubbles varying in their relative size, which do not move. Grains of quartz, as observed by Tschermak ('Mineral. Mittheil.,' 1872, p. 108) in specimens brought by Favre from the lava streams lower down the mountain, do not occur in this specimen. A fluidal structure is barely indicated. The rock may be named a hornblende-andesite. 1 have compared the slide with one from the upper part of Ararat (lent me by Professor Judd), and with my own collection of andesites and allied rocks from Auvergne, Germany, Hungary, Italy, Old Providence Island, and the Andes, but it differs varietally from all.

III. " On the Distribution of Strain in the Earth's Crust resulting from Secular Cooling, with special Reference to the Growth of Continents and the Formation of Mountain-chains." By CHARLES DAVISON, M.A., Mathematical Master at King Edward's High School, Birmingham. Communicated by Prof. T. G. BONNEY, D.Sc., F.R.S. Received April 7, 1887.

(Abstract.)

The paper is founded on—

1. Sir W. Thomson's and Professor G. H. Darwin's researches on the rigidity of the earth.

2. Sir W. Thomson's investigation on the secular cooling of the earth.

3. The contraction theory of mountain formation.

I. *The Distribution of Strain in the Earth's Crust resulting from Secular Cooling.*

The following problem is solved:—A globe, of radius r, is surrounded by a number of concentric spherical shells, called A_1, A_2, A_3 . . . ., of thickness a_1, a_2, a_3 . . . . respectively. The globe remaining at its initial temperature, the shell A_1 is cooled by $t_1°$, the shell A_2 by $t_2°$, in the same time, and so on. The linear coefficient of expansion being e, and the same for all the shells, it is required to find the distribution of strain resulting from this method of cooling.

An expression is found giving the change of radius of the inner surface of any shell. Supposing all the shells to be of equal thick-

ness a, the change of radius of the inner surface of the shell A_{n+1} is proportional to

$$\frac{e}{(r+na)^2}\left[(r+na)^3(t_{n+1}-t_n)+(r+\overline{n-1}.a)^3(t_n-t_{n-1})+\ \cdots\right.$$
$$\left.+(r+a)^3(t_2-t_1)+r^3t_1\right].\quad.\quad.\quad(1.)$$

i.e., if the shells be infinitely thin, to

$$\frac{e}{(r+na)^2}\int_r^{r+na}z^3.\frac{dt}{dz}\,dz,\quad.\quad.\quad.\quad.\quad.\quad.\quad(2.)$$

t being proportional to the rate of cooling of any shell.

If this expression be positive for any shell, the shell is stretched; if negative, it is crushed or folded.

To apply this problem to the case of the earth, the law of cooling taken is that which follows from Sir W. Thomson's solution, in his memoir on the secular cooling of the earth. The expression in the form (2) proves unserviceable, and therefore the expression (1) is made use of as follows :—

Taking the time since solidification provisionally at 174,240,000 years, it is shown that the rate of cooling (dv/dt) is practically insensible at a depth of 400 miles. The radius of a sphere equal to the earth in volume being about 3959 miles, the earth is supposed to be constituted as follows :—A central globe, 3559 miles in radius, at the initial temperature of the earth, which as yet has not sensibly cooled, surrounded by 400 concentric spherical shells, each one mile in thickness, the rate of cooling in each shell being uniform throughout, and equal to its value at the outer surface at that shell.

The results of the calculation are shown by the curve in the figure accompanying the paper, and the following conclusions are deduced, taking the time since consolidation provisionally at 174,240,000 years :—

1. Folding by lateral pressure takes place only to a certain depth (about five miles) below the earth's surface, and below this depth changes to stretching by lateral tension.

2. Stretching by lateral tension, inappreciable below a depth of 400 miles, increases from that depth towards the surface; it is greatest at a depth of 72 miles (*i.e.*, just below the depth at which the rate of cooling is greatest); after this it decreases, and vanishes at a depth of about five miles.

3. Folding by lateral pressure commences at a depth of about five miles, and gradually increases, being greatest near the surface of the earth.

No great importance is attributed to the numerical results. The

conclusions are given for their qualitative rather than their quantitative value. They depend also on the assumption that the earth's surface is smooth and spherical.

The following laws are also shown to be approximately true:—

1. The depth of the surface at which folding by lateral pressure vanishes, and the depth of the surface at which stretching by lateral tension is greatest, both increase as the square root of the time that has elapsed since the consolidation of the globe.

2. Folding by lateral pressure was effected most rapidly in the early epochs of the world's history as a solid globe, and, since then, the total amount of rock folded in any given time decreases nearly in proportion as the square root of the time increases.

3. A law, similar to No. 2, for stretching by lateral tension.

II. *The Rev. O. Fisher's Argument on the Insufficiency of the Contraction Theory.*

The argument is described (see 'Phil. Mag.' for Feb., 1887). It is shown to be inconclusive on the following grounds:—

1. It assumes that the cooling of the earth to its present condition was instantaneous.

2. If instantaneous cooling were possible, there would, it is shown, be no folding at all, but only stretching by lateral tension.

3. It assumes that the earth's surface was initially smooth and spherical, whereas Professor B. Peirce and Professor G. H. Darwin have both shown that vast continental wrinkles would be formed on the surface of a once viscous earth by the diminishing velocity of rotation resulting from tidal friction.

III. *The Effects of Crust-stretching and Folding on the Evolution of the Earth's Surface-features.*

1. Owing to the pressure of the continental masses, crust-stretching by lateral tension takes place principally beneath the ocean-basins, therefore deepening them and contributing to their permanence. This effect must have been greatest in early geological periods, when the surface of greatest stretching was close to the surface of the earth.

2. In another part of the paper it is shown that the amount of crust-stretching is considerably greater than the amount of crust-folding, due directly to secular cooling. Folding beneath the ocean-bed will therefore do little but diminish its rate of subsidence. The effects of folding in changing the forms of the earth's surface-features must be most apparent in continental areas, especially along those coasts where the slope towards the ocean-depths is most rapid (*i.e.,* in the districts where earthquake and volcanic action are known to be most prevalent). In the coast regions, also, the products of conti-

nental denudation are chiefly deposited.   Hence, the continents grow by the formation of mountain-chains along their borders.

3. The rate of mountain-making, and therefore also that of continental evolution, diminishes with the increase of the time.

IV. " Note on the Geological Bearing of Mr. Davison's Paper." By T. G. BONNEY, D.Sc., LL.D., F.R.S., Professor of Geology in University College, London.   Received April 7, 1887.

The results obtained by Mr. Davison throw light upon one or two matters in regard to the petrology of the older rocks, which have always appeared to me difficult of explanation.   I venture therefore to add a brief note to his paper, written from the point of view of a geologist.   He throws light especially on the following matters :—

(1.) Among the older rocks the great foldings and their results, such as cleavage, appear to have occurred when the beds formed the upper layers of the earth's crust.   Thus the Ordovician rocks of North Wales were cleaved anterior to the deposit of the Silurian ; the Carboniferous, and other Palæozoic rocks of South-west Britain and Britanny were plicated and cleaved, geologically speaking, shortly after their deposition.   The great foldings in the Scotch Highlands occurred, in great part at least, in Silurian time.   The disturbance of the Lake District rocks, resulting in cleavage, must be placed between the end of the Silurian and the very beginning of the Carboniferous ; that of Southern Scotland, between perhaps yet narrower limits.   The first epoch of mountain making in the Central Alps, with its plication and cleavage, immediately followed the deposition of the Eocene rocks.   The list might easily be extended.

(2.) The crystalline substratum often appears to be less modified than the overlying softer and more recent beds.   This I had attributed to the greater resistency of the former, but then could not see how to explain the foldings of the latter, if the others were comparatively uncompressed.   This, however, accords with Mr. Davison's results of the diminishing effects of compression, while the fact that in early geological times the " neutral zone " between compression and tension was comparatively near the surface of the earth, may explain the frequent parallel arrangement of the minerals in the older Archæan gneisses.   I do not now refer to the more marked changes, such as the intercalation of calcareous or micaceous rocks, of more felspathic or quartzose layers, whereby a stratification is simulated, if it be not recorded, but to the fact that very often a general parallelism may be